TITLE: SPOUTED BED ELECTRODES (SBE) FOR DIRECT UTILIZATION OF CARBON IN FUEL CELLS

AUTHOR: J.M. Calo (PI)

INSTITUTION: Brown University
Division of Engineering
Box D
Providence, RI 02912

PHONE NO.: (401) 864-1421

FAX NO.: (401) 863-9120

E-MAIL: Joseph_Calo@brown.edu

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1. ABSTRACT

OBJECTIVES
Carbon-oxygen fuel cells have been demonstrated that operate on very fine particles (10-1000 nm) of low-ash, turbostratic carbon. As impressive as these devices are, however, a number of problems remain to be solved before this technology can successfully operate on many different carbon sources on a large scale. The use of coal and biomass-derived carbons, for example, requires a fuel cell design that can handle high amounts of ash, and larger particles. It is proposed to adapt the concept of particulate spouted bed electrodes (SBE) to the carbon-oxygen fuel cell.

In our laboratory, we have developed spouted bed electrodes (SBE) for point source metals recovery. In these devices an aqueous solution containing metal ions is introduced as a high velocity jet at the bottom of a conical vessel *via* a central draft tube. This liquid jet entrains particles that disengage from the jet in a region above the draft tube known as the "fountain." The particles are then distributed radially to the bed periphery by the distributor, where they fall onto the cathodic "feeder cone" at the reactor bottom, and are directed back to the inlet of the draft tube for re-entrainment. Metal is deposited on the particles when they are in contact with the cathodic bottom cone. The "pumping action" of the spout continually circulates the particles through the vessel; upwards in the spout, and downwards in the annular region. We have successfully recovered Ag, Au, Cu, Ni, Sn, and Cd from various aqueous solutions with this system at high current densities and high current efficiencies.

The objectives of this project are to explore the extension/application of SBE-like systems to direct carbon fuel cells. More specifically: (1) to adapt SBE CFD codes to simulate the expected hydrodynamics of DCFC; and (2) to perform simulated experiments of fluid-particle circulation in a 2D rectangular spouted vessel hydrodynamics apparatus.

ACCOMPLISHMENTS

- The CFD hydrodynamics model of the rectangular spouted bed has been adapted to the DCFC application.
- Preliminary results involving particle loading and flow rate have been used to identify conditions for good particle contact with the inclined vessel bottom (anode), particle recirculation.
- Both two-phase (liquid-solid) and three-phase (liquid-solid-CO_2 gas) hydrodynamics have been examined.
- The 2D spouted vessel hydrodynamics apparatus (SVHA) has been retrofit for simulated molten carbonate/carbon slurry experiments.

FUTURE WORK

- The CFD model will continue to b e developed to explore the behavior of the SBE/DCFC system
- The experimental apparatus will be used to conduct experiments using water-glycerol mixtures and carbon particles of varying sizes as a function of loading and flow rate.

2. LIST OF PAPERS AND PRESENTATIONS, AND STUDENTS RECEIVING SUPPORT UNDER THIS GRANT

• Conference Presentations

"Hydrodynamic Reaction Model of a Spouted Bed Electrolytic Reactor," P.A. Shirvanian, and J.M. Calo, Paper No. 190a, presented at the AIChE 2003 Annual Meeting, San Francisco, CA, November 17, 2003.

"A Kinetic-theory Analysis of the Scale-up for the Hydrodynamics of a Rectangular Slot, Spouted Fluidized Vessel," P.A. Shirvanian and J.M. Calo, Paper No. 292g, presented at the AIChE 2003 Annual Meeting, San Francisco, CA, November 17, 2003.

• Papers

"An experimental investigation of the hydrodynamics of a rectangular, spouted vessel with a draft duct," P.A. Shirvanian, J.M. Calo, and G. Hradil, submitted to *Chem. Eng. Sci.,* 2003.

"Numerical Simulation of Fluid-Particle Hydrodynamics in a Rectangular Spouted Vessel," P.A. Shirvanian, J.M. Calo, and G. Hradil, submitted to *Int. J. Multiphase Flow,* 2003.

"Hydrodynamic Scaling of a Rectangular Spouted Vessel With a Draft Duct," P.A. Shirvanian and J.M. Calo, submitted to *Chem. Eng. J.,* 2003.

• Students Supported Under This Grant

Ian Tolle, Undergraduate Student